International Journal of ChemTech Research
CODEN (USA): IJCRGG, ISSN: 0974-4290, ISSN(Online):2455-9555
Vol.9, No.05 pp 489-499, 2016

Performance evaluation of Biodiesel-diesel-ethanol blends in a Diesel engine

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Abstract : This paper presents the study of Diesel-Palm Oil Biodiesel-Ethanol blends in a diesel engine for performance, combustion and emission. Firstly, solubility tests were done for various proportions of the fuel blends. Then, the stability of the fuel blends were checked at three different temperatures. The results of the solubility are also presented. Out of the stable blends, two blends were selected for property testing as per ASTM standards. Out of the two, one blend is selected for the investigation of performance, combustion and emission characteristics. The results were compared with diesel as base fuel. Results indicate that there is a decrease in CO, NO_x and Smoke emissions. The maximum pressure and HRR are higher than diesel. There is an increase of BTE along with load with slight increase in BSFC as compared to diesel.
Key words : Biodiesel, Ethanol, diesel-biodiesel-ethanol blends.

1. Introduction

Diesel engines are the necessary power source for various power generations, automotive and stationary power backups. Diesel engine produces lesser emissions compared to petrol engine. However, the volume of diesel engine worldwide giving a severe impact on the air pollution with cumulative emissions. Consumption of diesel in India is 2,438,000 barrels per day.

Also the emissions are affecting the health of people and plants significantly. More and more consumption of fossil fuels evacuate the oil reserves at a rapid rate. The projections of 30 year period of 1990 to 2020 from a survey resulted that the demand of fossil fuel will be three times and will give a severe impact on environment. Also the author suggested that Biodiesel [16-31] from vegetable oils are potential source for alternate fuels to replace or reduce the consumption of diesel [1].

Cheng Tung Chong et.al [2] studied the effect of oxygenated palm oil biodiesel in a diesel engine. It was observed that there was a delay in ignition which leads to lower cylinder pressure. Also there was an increase in BTE and CO_2 emissions.

BiplabK.Debnath et.al [3] investigated the effect of emulsified palm oil methyl ester. Due to emulsification, better efficiency was observed along with the reduction in BSFC. Also, NO_x emissions were reduced as the water reduces the cylinder temperature.

Luka Lesnik et.al [4] analysed the influence of biodiesel on the injection characteristics of a diesel engine. Results showed that advancing injection timing increases the in-cylinder pressure. There was a reduction in CO emissions and increase in NO_x emissions. Also, the EGT was reduced due to lower calorific value of the fuel.

BiplabK.Debnath et.al [5] explored the effect of compression ratio and injection timing of POME fuelled diesel engine. It was observed that the peak pressure and peak heat release rate were increased due to advancement of injection timing.

S.Nagaraja et.al [6] studied the effect of compression ratio on preheated palm oil biodiesel blends. Results showed that the brake power of palm oil biodiesel- diesel blend is higher than that of standard diesel at higher compression ratio and full load condition. There was an increase in mechanical efficiency and thermal efficiency and indicated mean effective pressure. Also, there was a reduction in CO and unburned hydrocarbon with increase in CO_2 emissions.

K.Muralidharan et.al [7] investigated the effect of biodiesel from waste cooking oil-diesel blends in a variable compression ratio engine. The EGT tends to reduce with increase in compression ratio. HC and NO_x emissions were increased while CO and CO_2 remains the same.

Alan C Hansen et.al [8] suggested that Ethanol, among the alcohols, can be used in a diesel engine as a blend with diesel to reduce or replace the dominance of diesel. Many researchers studied about ethanol-diesel blends in a diesel engine. Ethanol addition to diesel has some limitations such as lower calorific value, cetane number, and flash point. Also, ethanol-diesel blends phase separation issue, above 15% of ethanol content. To reduce these limitations, researchers used ethanol addition to diesel- biodiesel blends. Various researchers studied about these blends.

D.C.Rakopoulos et.al [9] evaluated the effect of using blends of ethanol and diesel. It was observed by the author that there was an increase of the BSFC, decrease in smoke density and NO_x emissions similar to diesel.

Labeckas et.al [10] examined the influence of ethanol and biodiesel addition to diesel fuel and reported about the effects on start of injection, ignition delay, combustion and maximum heat release rate, engine performance efficiency and emissions and the results were increase in heat release rate, decrease in CO, NOx and smoke compared to diesel.

Xiaoyan Shi et.al [11] studied the emission characteristics of ethanol-biodiesel and diesel fuel blends and reported that there was decrease in NOx and PM emissions from the blends.

M. Al-Hassan et.al [12] studied the solubility of diesel- ethanol blends and performance of diesel biodiesel ethanol blends in a diesel engine. The author reported that the blend containing 20% ethanol and 10% biodiesel from waste frying oil is stable for 2 hours. The author addressed the limitation of diesel-ethanol blends as phase separation with increase of ethanol content.

Karikalan L et.al [13] studied the effect of variation of injection pressure of jatropha biodiesel in a diesel engine. The results indicated that there was an increase in BTE with the increase in injection pressure.

Siva S et.al [14] produced biodiesel from the algae oil by transesterification. Results suggested that nano Calcium oxide from the egg shell acts as a catalyst in the transesterification of the algae oil.

Senthil R et.al [15] studied the influence of neem oil and mustard oil biodiesel in a single cylinder diesel engine. Results indicated that butyl esters of mustard oil has reduced HC, NO_x and smoke emissions.

Kapilan N et.al [16] studied the oxidative stability of biodiesel. It was observed that addition of antioxidants was a method to improve the oxidative stability of biodiesel.

2. Experimental Study

2.1 Solubility test

The fuels were blended together in different proportions. The stability of the blends was checked at three different temperatures being 5, 15 and 25°C. The status of the blends are presented in Table 1-3.

Table 1 Phase Stability

S.No	Diesel%	Ethanol%	POME%	>25°C	15°C	5°C
A1	75	20	5	Unstable	Unstable	Unstable
A2	70	20	10	Unstable	Unstable	Unstable
A3	65	20	15	Stable	Unstable	Unstable
A4	60	20	20	Stable	Unstable	Unstable
A5	55	20	25	Stable	Stable	Stable
A6	50	20	30	Stable	Stable	Stable

Table 2 Phase Stability

S.No	Diesel%	Ethanol%	POME%	>25°C	15°C	5°C
B1	70	25	5	Unstable	Unstable	Unstable
B2	65	25	10	Unstable	Unstable	Unstable
B3	60	25	15	Unstable	Unstable	Unstable
B4	55	25	20	Stable	Stable	Unstable
B5	50	25	25	Stable	Stable	Stable
B6	45	25	30	Stable	Stable	Stable

Table 3 Phase Stability

S.No	Diesel%	Ethanol%	POME%	>25°C	15°C	5°C
C1	65	30	5	Unstable	Unstable	Unstable
C2	60	30	10	Unstable	Unstable	Unstable
C3	55	30	15	Unstable	Unstable	Unstable
C4	50	30	20	Stable	Unstable	Unstable
C5	45	30	25	Unstable	Unstable	Stable
C6	40	30	30	Stable	Stable	Stable

2.2 Properties of Fuels

Stable blends are tested for various properties as per ASTM blend standards. The properties are tabulated in Table 4.

Table 4 Properties of Fuel

Property	Diesel	Ethanol	POME	D55B25E20
Density (kg/m^3) At 30°C	855	821.6	866	851
Kinematic viscosity (cst) (at 40°C)	2.95	1.1	`4.802	3.0425
Flash point (°C)	60 - 80	13	174	10
Calorific value (kJ/kg)	43000	27000	36764	38241
Oxygen content (wt %)	-	35	11.7	0.62
Cetane number	52	8	63	46

2.4 Engine Setup

The experimental setup is as shown in Figure 1 and the specifications are tabulated in Table 5. The test fuel was checked for combustion, performance and emission in a single cylinder, four stroke, direct injection, constant speed, Kirloskar diesel engine. The volume displaced by the piston was 662 cc and the compression ratio was 17.5:1. The crank angle at which the fuel was injected was 23 degree before TDC. The operating speed of engine was 1500 rpm and the maximum power generated by the engine was 4.4 kW.

The dynamometer used was eddy current type .A piezoelectric pressure transducer of Kistler make was used to measure the cylinder pressure. Pressure from the combustion chamber is captured and fed to data acquisition system for further combustion analysis. The fuel consumption was measured by using the time taken to consume 10cc of fuel. The performance characteristics were calculated using the voltage and current. The emissions were measured using an AVL DI GAS Gas Analyser and Smoke meter.

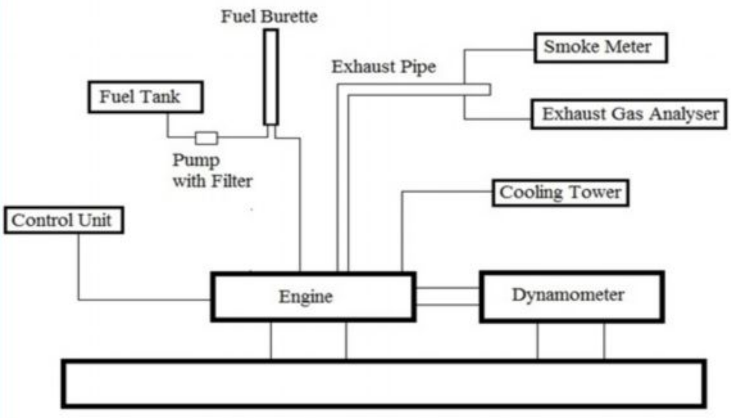

Figure 1: Test Engine Layout

Table 5 Engine Specifications

Name	Kirloskar
Number of cylinders	1
Displacement volume	662 cc
Bore× stroke	87.5 mm ×110 mm
Compression ratio	17.5:1
Operating speed	1500 rpm
Injection timing	23 deg BTDC
Power	4.41 kw

3. Results and Discussions

3.1 Solubility Tests

Out of 18 blends tested for solubility, five blends were stable in all the three temperatures (5°C, 15°C, >25 °C).From the table 8, it can observed that blends of ratio higher than 1:1 (ethanol: biodiesel) are stable in the range of 5°C, 15°C and >25 °C. Similar results were reported by Alan C Hansen.

Table 6 Stable Proportions

S.No	Diesel%	Ethanol%	POME%	>25°C	15°C	5°C
A5	55	20	25	Stable	Stable	Stable
A6	50	20	30	Stable	Stable	Stable
B5	50	25	25	Stable	Stable	Stable
B6	45	25	30	Stable	Stable	Stable
C6	40	30	30	Stable	Stable	Stable

3.2 Performance Characteristics

3.2.1 Brake Thermal Efficiency

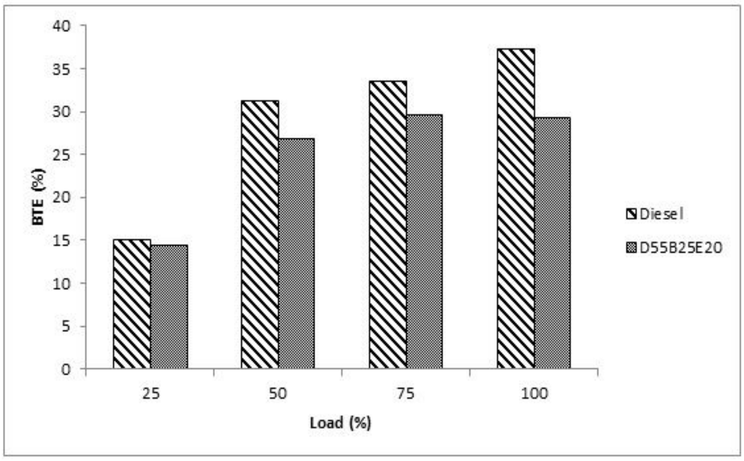

Figure 2: BTE

The Figure 2 shows the variation of Brake thermal efficiency of the blend as compared to diesel with respect to load. It is observed that the BTE of D55B25E20 is lower than that of diesel due to lower calorific value of the blend as compared to diesel.

3.2.2 Brake Specific Fuel Consumption

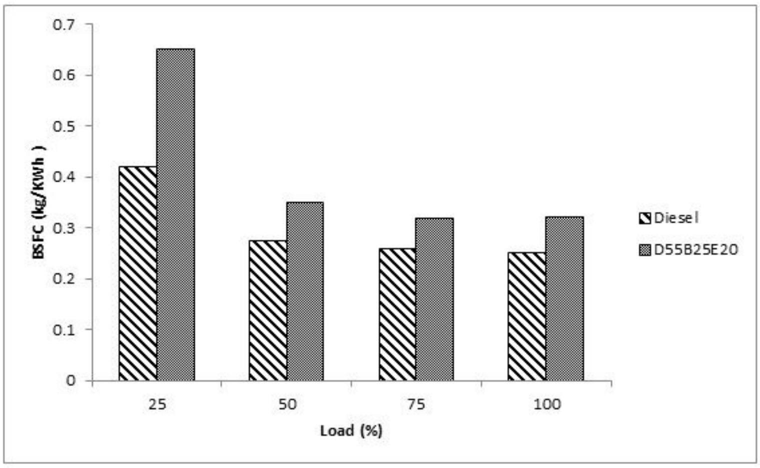

Figure 3: BSFC

The Figure 3 shows the variation of Brake Specific Fuel Consumption of the blend as compared to diesel with respect to load. It is observed that the BSFC of the D55B25E20 is higher than that of diesel at all loads as the calorific value of the blends are lower than diesel due to the presence of ethanol in the blends. Also latent heat of vaporisation of blends is higher. So it is consuming more time to evaporate and reducing the temperature of the combustion chamber, at lower loads.

3.2.3 Exhaust Gas Temperature

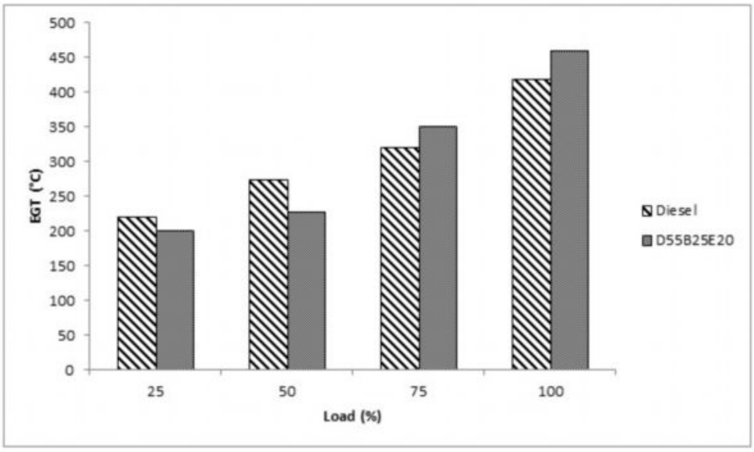

Figure 4: EGT

The Figure 4 shows the variation of Exhaust Gas temperature of D55B25E20 as compared to diesel with respect to load. It is observed that the EGT of the blend is lower than diesel up to part load. This is due to higher latent heat of evaporation of the fuel blend. Also, with the increase of load, the EGT of the blend is increasing.

3.3 Combustion Characteristics

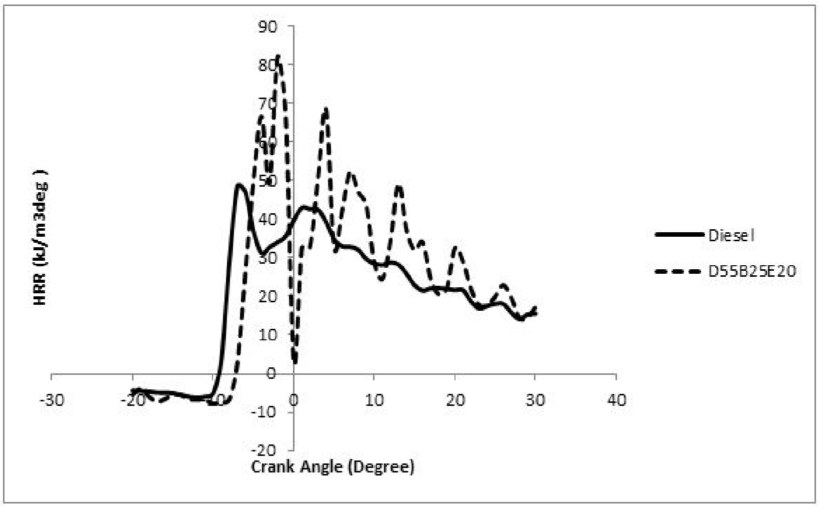

Figure 5: HRR

The Figure 5 shows the variation of heat release rate of blends at full load as compared to diesel with respect to Crank angle.The maximum heat release for diesel was 47 kJ/m3deg at 6^{o}CA, and for D55B25E20 was 82 kJ/m3deg at -2^{o}CA. It is observed that the maximum heat release of the blends is higher than that of diesel. This can be due to higher oxygen content of the fuel. Also, the reactivity of the oxygen is better at higher temperatures.

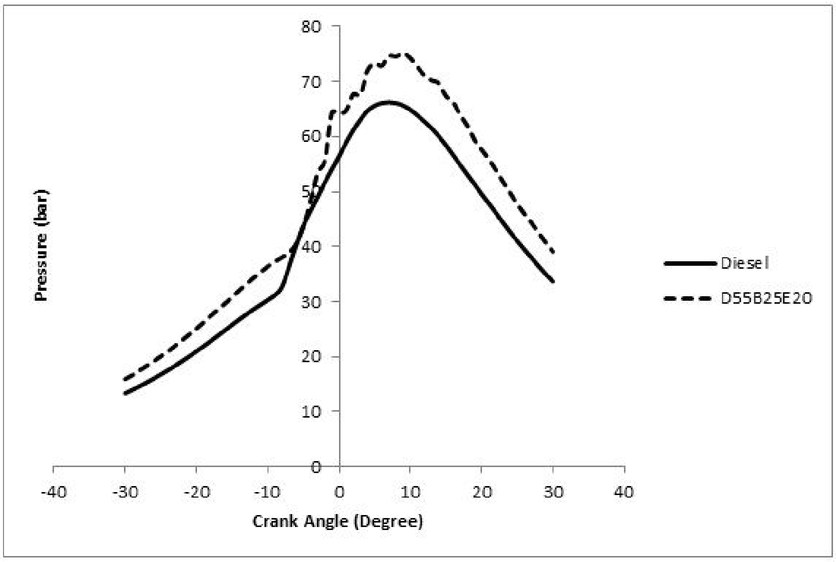

Figure 6: Cylinder Pressure

The Figure 6 shows the variation of pressure of blends at full load as compared to diesel with respect to Crank angle. The maximum pressure for diesel was 66 bar at 7^{o}CA, and for D55B25E20 was 75 bar at 6^{o}CA .It is observed that the cylinder pressure of both the blends is higher than that of diesel. This can be due to rapid combustion due to the accumulation of the fuel.

3.4 Emission Characteristics

3.4.1 Carbon Monoxide

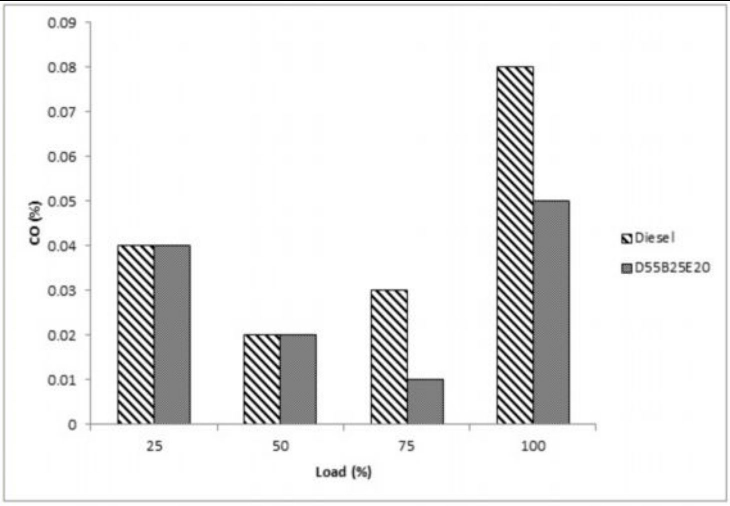

Figure 7: CO

The Figure 7 shows the variation of Carbon Monoxide level of blends as compared to diesel with respect to load.It is observed that the CO of blend is lower than that of diesel after part load. At higher loads, the average temperature of the combustion chamber increases, thereby leading to more oxygen activity of the blend. Hence, better complete combustion of the fuel takes place, reducing CO emissions.

3.4.2 Hydrocarbons

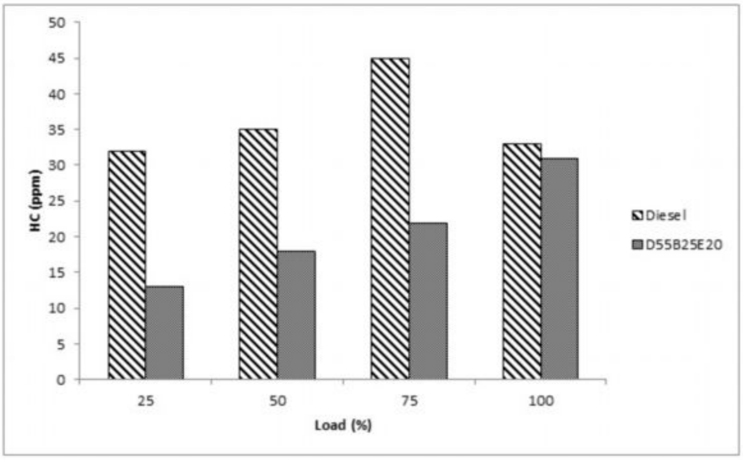

Figure 8: HC

The Figure 8 shows the variation of unburnt hydrocarbon level of blends as compared to diesel with respect to load. It is observed that the HC of D55B25E20 is lower than diesel. As the temperature of the cylinder is very high at full load, more complete combustion occured leading to lower HC emissions. This is presented in HRR increase at full load.

3.4.3 Oxides of Nitrogen

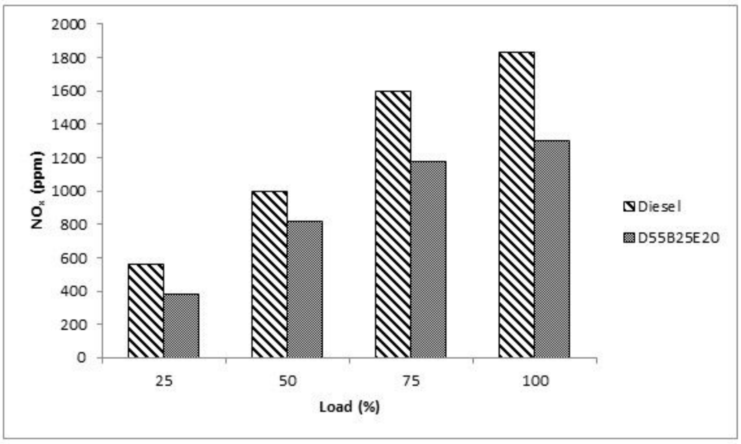

Figure 9: NOx

The Figure9 shows the variation of oxide of nitrogen level of the blend as compared to diesel with respect to load. It is observed that the $NO_x$of blendis lower than that of diesel. This is due to ethanol content which reduces the combustion temperature and prevents the formation of NO_x. Also, due to low calorific value of the blends, the cylinder temperature is lower than that of diesel. However, at full load, the NO_x emissions are higher as compared to lower loads.

3.4.4 Smoke

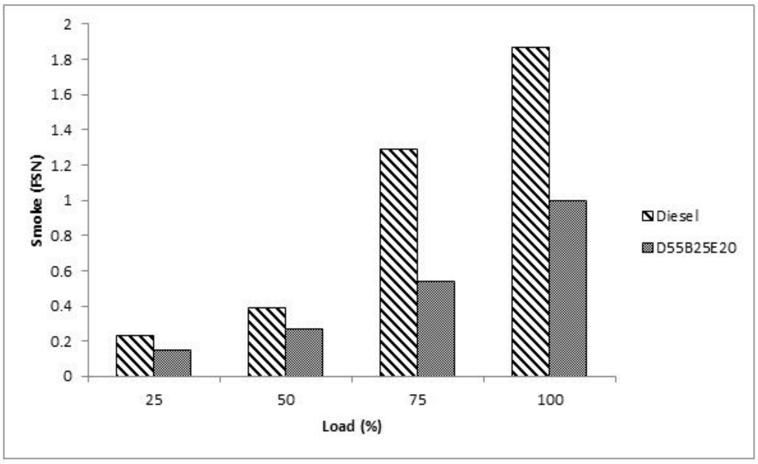

Figure 10: Smoke

The Figure 9 shows the variation of smoke level of D55B25E20 as compared to diesel with respect to load. It is observed that the smoke of blend is lower than that of diesel. This can be due to better combustion of fuel in the combustion chamber. Also the oxygen content of the fuel is higher.

4. Conclusion

An experimental investigation for the blends of Diesel -POME-Ethanol has been performed and the following results are suggested. At full load, as compared to diesel,the characteristics of D55B25E20 are

- BTE reduced by 21%
- BSFC increased by 27%
- Maximum pressure increased by 11%
- HRR increased by 74%

- CO decreased by37 %
- HC reduced by 6%
- NO_x reduced by 28%
- Smoke decreased by 46%

Nomenclature

D55 B25 E20	55% Diesel, 25% Biodiesel, 20 % Ethanol
POME	Palm oil Methyl Ester
TFC	Total fuel consumption
BSFC	Brake specific fuel consumption
BTE	Brake Thermal Efficiency
ME	Mechanical Efficiency
HRR	Heat Release Rate
CA	Crank Angle
CO	Carbon Monoxide
HC	Hydrocarbons
NO_x	Oxides of Nitrogen
EGT	Exhaust Gas Temperature
BMEP	Brake Mean Effective Pressure
ppm	Parts per million
FSN	Filter Smoke Number
PM	Particulate Matter

5. Acknowledgement

Author would sincerely thank the support by Dr.M.Jaikumar of Automobile Engineering department for doing the project. Author would also thank the support by the UG student Mr.Aravindan, for the assistance in solubility test of the fuel blends.

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